REMARKS

Claims 19, 61, and 66-93 are currently pending. Claims 38, 41, 43, 44, 47, 52, and 53 have been canceled without prejudice or disclaimer. Claims 19 and 61 have been amended. Support for the amendment of claims 19 and 61 is found in the originally filed application, especially page 8, line 19, and page 7, lines 6-9. New claims 66-87 have been added to enhance the scope of Applicant's patent coverage. New independent claims 67, 70, and 73 are supported by the original claims. New independent claims 76 and 79 are supported by the original claims and page 12, lines 6-12, of the originally filed application. New dependent claims 66, 68, 69, 71, 72, 74, 75, 77, 78, and 80-93 are supported by page 1, lines 3-6, page 7, lines 2-5, and elsewhere in the originally filed application. It is respectfully submitted that no new matter has been added.

35 U.S.C. 112, second paragraph, Rejections

The Patent Office rejected claims 38 and 53 under 35 U.S.C. 112, second paragraph, as being indefinite.

This rejection is moot as claims 38 and 53 have been canceled.

Written Description Rejection

The Patent Office rejected claim 41 under 35 U.S.C., first paragraph, as failing to comply with the written description.

This rejection is moot as claim 41 has been canceled.

35 U.S.C. 102(e) Rejections

The Patent Office rejected claims 19, 38, 41, 43, 44, 47, 52, 53, and 61 under 35 U.S.C. 102(e) as being clearly anticipated by Graff, U.S. Patent No. 6,570,325.

Claims 19, 61, and 66-81 are currently pending.

The Patent Office has asserted that Graff discloses the claimed invention on column 1, lines 19-34 and 53-57; column 1, line 60, through column 2, line 36; column 2,

lines 45-48; column 3, lines 13-21 and 53-67; column 4, lines 11-31 and 36-41; column 4, line 56, through column 5, line 38; column 5, line 61, through column 6, line 4; column 6, line 22, through column 8, line 10; column 9, lines 36-50; column 10, line 24, through column 11, line 50; column 11, line 60, through column 12, line 5; column 12, lines 18-53; and column 14, lines 4-15.

Graff fails as an anticipatory reference for at least the following reasons:

1) Graff does not teach or suggest a sub-layer that is from 0.4 to 1.5 nanometers thick. The 50 to 200 Angstroms (i.e., 5 to 20 nanometer) layer that is taught falls outside of the claimed range of sub-layer thicknesses. Proper thickness of the sub-layer in Applicant's claimed invention prevents the formation of a crystalline structure such that the sub-layer is amorphous. The range of 0.4 to 1.5 nanometer (4 to 15 Angstrom) thickness for a sub-layer is disclosed on page 7, line 16, through page 8, line 3, of Applicant's original filed disclosure as being important "to avoid the formation of a crystalline structure"... where "the resulting structure has the form of an essentially or substantially amorphous material thereby beneficially inhibiting diffusion throughout the material."
2) Graff discloses in column 7, lines 37-40, mismatched lattices, but does teach or suggest an amorphous layer.
3) As to alternating sub-layers of tantalum and lanthanum, tantalum and copper, tantalum and scandium, tantalum and yttrium, tantalum and tungsten nitride, or tantalum and tantalum nitride, Graff does not teach or suggest the claimed combination. In column 6, lines 29-32, Graff discloses tantalum and yttrium as metals that may be used for barrier layers, but does not disclose or suggest an alternating relationship between tantalum and yttrium sub-layers. In column 8, lines 48-63, Graff discloses lanthanide metals may be used for the decoupling layer, but does not disclose or suggest an alternating relationship between tantalum and lanthanum sub-layers. Graff also fails to teach tungsten nitride. The choice of materials by Applicant is inventive with Applicant's reasoning provided from page 11, line 3, through page 12, line 13, of the Application as filed. Adhesiveness, formation of a dominant interface, and temperature stability have all factored into the material combinations set forth in Applicant's disclosed

invention.

In regard to the deficiency noted in point 2 above about "amorphous" sub-layers, it is noted that on page 4, lines 17-18, of the November 14 2008 Office Action, the Patent Office has asserted "...There are no limitations on the thicknesses where interfaces between the sub-layers inherently inhibit the formation of a crystalline lattice..."

The passage from the November 14 2008 Office Action is believed to be meant to correspond to column 5, lines 9-10, of Graff. For the sake of placing Graff's teachings in proper context, Graff, from column 4, line 63, through column 5, line 18, is reproduced immediately below as follows:

> Although FIG. 1 shows a barrier stack with decoupling layers on both sides of a barrier layer, the barrier stacks can have one or more decoupling layers and one or more barrier layers. There could be one decoupling layer and one barrier layer, there could be multiple decoupling layers on one side of one or more barrier layers, or there could be one or more decoupling layers on both sides of one or more barrier layers. The first layer of the barrier stack can be either the decoupling layer or the barrier layer, and the last layer can be either. The important feature is that the barrier stack have at least one decoupling layer and at least one barrier layer. The barrier layers are typically in the range of about 100-400 .ANG. thick, and the decoupling layers are typically in the range of about 1000-10,000 .ANG. thick, although there are no limits on thickness.
> Although only one first barrier stack is shown in FIG. 1, the number of barrier stacks is not limited. The number of barrier stacks needed depends on the substrate material used and the level of permeation resistance needed for the particular application. One or two barrier stacks should provide sufficient barrier properties for some applications. The most stringent applications may require five or more barrier stacks.

Preceding the clause "although there are no limits on thickness," is the rest of the sentence which reads as follows: "The barrier layers are typically in the range of about 100-400 .ANG. thick, and the decoupling layers are typically in the range of about 1000-10,000 .ANG. thick." The juxtaposed clause "where interfaces between the sub-layers inherently inhibit the formation of a crystalline lattice" that the Patent Office placed after "although there are no limits on thickness," is not to be found in the cited passage of Graff.

The word "amorphous" does not appear in Graff. Graff does refer to lattices.

Graff's teaching with regard to lattices is found in column 7, lines 10-40, reproduced immediately below as follows:

> When the barrier layers are made of the same material, they can be deposited either by sequential deposition using two or more sources or by the same source using two or more passes. If two or more deposition sources are used, deposition conditions can be different for each source, leading to differences in microstructure and defect dimensions. Any type of deposition source can be used. Different types of deposition processes, such as magnetron sputtering and electron beam evaporation, can be used to deposit the two or more barrier layers.
>
> The microstructures of the two or more barrier layers are mismatched as a result of the differing deposition sources/parameters. **The barrier layers can even have different crystal structure.** For example, Al.sub.2 O.sub.3 can exist in different phases (alpha, gamma) with different crystal orientations. The mismatched microstructure can help decouple defects in the adjacent barrier layers, enhancing the tortuous path for gases and water vapor permeation.
>
> When the barrier layers are made of different materials, two or more deposition sources are needed. This can be accomplished by a variety of techniques. For example, if the materials are deposited by sputtering, sputtering targets of different compositions could be used to obtain thin films of different compositions. Alternatively, two or more sputtering targets of the same composition could be used but with different reactive gases. Two or more different types of deposition sources could also be used. In this arrangement, the **lattices** of the two or more layers are even more mismatched by the different microstructures and **lattice** parameters of the two or more materials.

Graff does not provide a teaching for amorphous sub-layers that form a diffusion barrier. Graff's disclose above that "**The barrier layers can even have different crystal structure**" is not a teaching of amorphous sub-layers. Presumably, Graff's barrier layers could be polycrystalline or monocrystalline.

As to pages 9-12 of the November 14 2008 Office Action, Applicant asserts that Graff does not teach a substantially identical structure to that disclosed by Applicant. It is noted, for example, that the thicknesses of the sub-layers in Applicant's claimed invention are thinner and do not overlap with the layer ranges of Graff.

On page 10 of the November 14 2008 Office Action, the Patent Office asserted that in Applicant's specification on page 5, lines 5-14, and page 9, lines 3-14, Applicant discloses the claimed characteristics are inherent. This is not so. In order to provide

proper context, Applicant reproduces immediately below, from page 6, line 5, through page 7, line 9, from Applicant's specification as filed (the Patent Office cite to page 5, lines 5-14 is believed to have been in error):

> An enlarged view of this last interface is shown in FIG. 2, which shows the microstructure of the barrier material 210. In this figure, the grain boundaries 215 can be observed to be pathways 220 through the diffusion barrier 210 which allows one or both of the materials 230, 235 present to pass into the other, and thus, potentially degrade the electrical performance or reliability of the circuit.
>
> **Conventional diffusion barrier materials include crystalline materials such as titanium nitride (TiN), and tantalum nitride (TaN). Copper is able to diffuse through the grain boundaries 215 in these materials 230, 235, as the crystalline materials form the grain boundaries 215 where two adjacent crystalline structures meet.** Copper atoms drift through the grain boundaries 215 and diffuse into the underlying structures 230, 235.
>
> A diffusion barrier 315 in accordance with this invention is shown in FIG. 3. The diffusion barrier 315 includes a stack of very thin layers 350, 360, generally of alternating composition. In most embodiments, this might be a stack of two alternating layers of materials, such as copper (Cu) and tantalum (Ta). However, it is also possible to use three or more different materials.
>
> Each layer preferably has a thickness in a range of about two atoms to about fifteen atoms (0.4 to 4.5 nm), and more preferably has a thickness in a range of about two atoms to about ten atoms (0.4 to 3.0 nm), and even more preferably has a thickness in a range of about two atoms to about five atoms (0.4 to 1.5 nm).
>
> **To overcome the problems associated with grain boundaries mentioned above, the diffusion barrier layers 350, 360 in the present invention are substantially amorphous.** Since the diffusion barrier layers 350, 360 are not crystalline, there are no grain boundaries to extend through the layer 315 for the copper (or other chemical species) to drift or diffuse through.

Applicant's Figure 2 does show problems with the prior art. Applicant discloses a portion of his solution in the above passage.

As to page 9, lines 3-14, of Applicant's disclosure, the following passage is reproduced below:

> In FIG. 4, an atomic scale magnification of the layers of FIG. 3 is shown. As seen in FIG. 4, the individual layers of FIG. 3 are preferably no more than 2-5 atomic layers thick. Because of the strong binding of the interface 470(a) . . . (n), generally 470, between each of the layers, there is no regular crystal structure in

> the 2-5 atom thick layer between interfaces 470. This region could be considered to be the `bulk` of each of the layers. The nature of the surface binding energy is such that it dominates the normal tendency for the bulk atoms to form a conventional crystal lattice, in effect, inhibiting the formation of a lattice. Without a regular crystalline lattice, there are no breaks in the lattice that would constitute a grain boundary. Because there are no grain boundaries, the physical effect of work hardening is inhibited, resulting in a diffusion barrier with improved structural flexibility. Therefore, the material of FIG. 4 is a substantially amorphous, multilayer solid material and is highly resistant to the diffusion of a chemical species through the material.

In the above passage, Applicant explains the theory behind a portion of his invention.

35 U.S.C. 103(a) Rejections

On page 12, of the November 14, 2008, Office Action, the Patent Office rejected claims 19, 38, 41, 43, 44, 47, 52, 53, and 61, in the alternative, under 35 U.S.C. 103(a) as being unpatentable over Graff, U.S. Patent No. 6,570,325.

It is noted that Graff does not teach or suggest copper, scandium, or tungsten nitride and does not teach or suggest a sub-layer thickness range of 0.4 to 4.5 nm or 0.4 to 1.5 nm, Graff does not make obvious the currently pending claims.

As to the bottom of page 13 of the November 14, 2008, Office Action, Applicant disagrees with the assertion that "it would have been an obvious matter of design choice bounded by well known manufacturing constraints and ascertainable by routine experimentation and optimization to arrange the layers of Graff as claimed because applicant has not disclosed that, in view of the applied prior art, the arrangement is for a particular unobvious purpose, produces an unexpected results, or is otherwise critical, and it appears prima facie that the process would possess utility using another arrangement."

Applicant's background of the invention has set out the problem others have not been able to solve, but Applicant has found a solution. As described on page 3 of Applicant's disclosure, there have been attempts to develop amorphous diffusion barriers in light of the primary failure mechanism of a diffusion barrier by grain boundary diffusion, stated on page 2 of Applicant's disclosure. A problem with the prior art solutions described on page 3 of Applicant's disclosure is that the diffusion barriers are

difficult to reliably fabricate with satisfactory chemical control. "And the multilayer, discontinuous grain boundaries approach does not scale well to the very think thicknesses required for barriers in future interconnect generations..." (page 3 of Applicant's disclosure).

Furthermore, on page 15 of the November 14, 2008, Office Action, the Patent Office rejected claims 19, 38, 41, 43, 44, 47, 52, 53, and 61 under 35 U.S.C. 103(a) as being unpatentable over Graff, in view of Hegde, U.S. Patent No. 6,136,682.

Graff has been discussed above.

The Patent Office referred to the Office Action dated October 27, 2007, for application of Hegde against certain claimed subject matter, none of which is currently pending. Applicant's response to Hedge is provided below.

The claims of Hegde's patent refer to a silicon-containing layer, a base layer, or a substrate, upon which is disposed a composite barrier layer comprising a titanium nitride layer in direct contact with a tantalum nitride layer or a first amorphous barrier layer upon which is formed a second amorphous barrier layer, and upon which is formed a copper-containing layer or metallic layer (see claims 1, 9, and 16). Hegde, as noted in Applicant's response to the Office Action dated October 27, 2007, disfavors a barrier layer of more than two layers.

The 400 Angstrom barrier layer of Hegde comprises two 200 Angstrom layers. As a 200 Angstrom layer is a 20 nanometer layer, the range taught by Hegde falls outside of Applicant's claimed range of 0.4 to 1.5 nanometers. The range of 0.4 to 4.5 nanometer (4 to 15 Angstrom) thickness for a sub-layer is disclosed on page 7, line 16, through page 8, line 3, of Applicant's original filed disclosure as being important "to avoid the formation of a crystalline structure"... where "the resulting structure has the form of an essentially or substantially amorphous material thereby beneficially inhibiting diffusion throughout the material."

Hegde does not disclose tungsten, scandium, lanthanum, or yttrium. Hegde teaches a two layer barrier layer where one layer is titanium nitride and the other layer is tantalum nitride.

Dependent claims have been added to further define Applicant's claimed invention.

The Patent Office is respectfully requested to reconsider and remove the rejections of claim 41 under 35 U.S.C. 112, first paragraph, claims 38 and 53 under 35 U.S.C. 112, second paragraph, claims 19, 38, 41, 43, 44, 47, 52, 53, and 61 under 35 U.S.C. 102(e) based on Graff, and claims 19, 38, 41, 43, 44, 47, 52, 53, and 61 under 35 U.S.C. 103(a) based on Graff, whether or not in combination with Hegde. Allowance of currently pending claims 19, 61, and 66-93 is earnestly solicited.

Serial No.: 10/674,853
GAU: 2822
Respectfully submitted:

Walter J. Malinowski February 9, 2009

Walter J. Malinowski Date
Reg. No. 43423

Customer No.: 29683

HARRINGTON & SMITH, PC
4 Research Drive
Shelton, CT 06484-6212

Telephone: 203-925-9400, extension 19
Facsimile: 203-944-0245
Email wmalinowski@hspatent.com

CERTIFICATE OF MAILING

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

2.10.2009

Date

Name of Person Making Deposit